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(54) Acoustic range finder for monitoring level of material

(57) In an acoustic range finding system, such as may be used for monitoring the level of particulate solids or liquids, a first pulse of high frequency sound is transmitted, a first echo is received in response to the first pulse from an environment in which the system is to be used, and a mask is stored the profile of which represents the variation of the first echo with time (Fig 2). A second pulse of high frequency sound is transmitted subsequent to the first pulse and a second echo is received, the echo being reflected from the surface of material whose level it is desired to detect, and is converted into a return echo profile (1-5, Fig 1). The mask profile is subtracted from the return echo profile to isolate a true echo profile (Fig 3) representative of the surface of material and the true echo (4) is extracted from the true echo profile. The mark profile may be adapted to environmental changes, e.g. temperature.

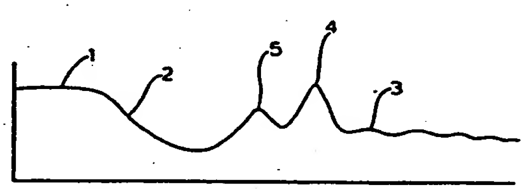

FIG 1

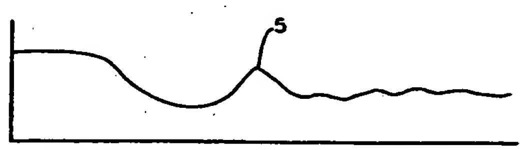

FIG 2

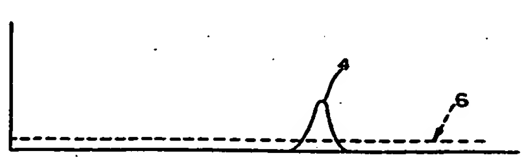

FIG 3

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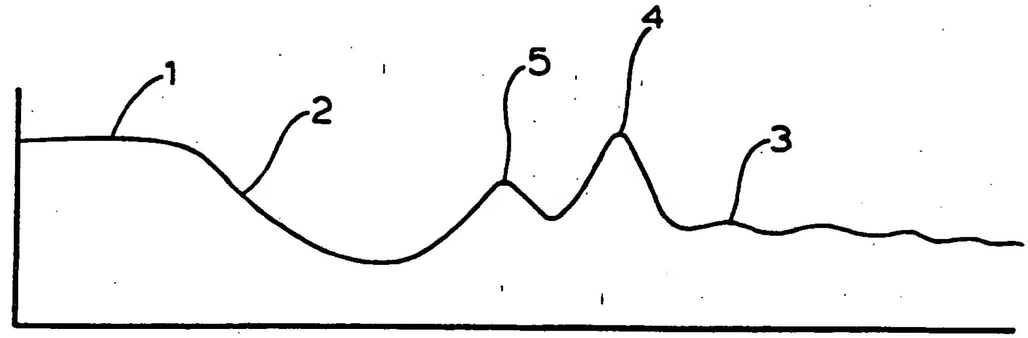

FIG 1

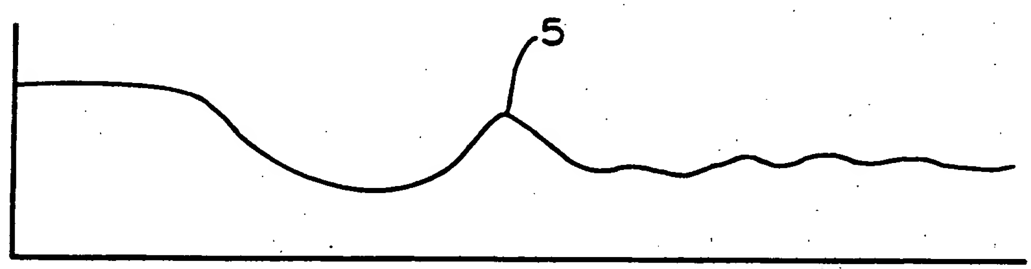

FIG 2

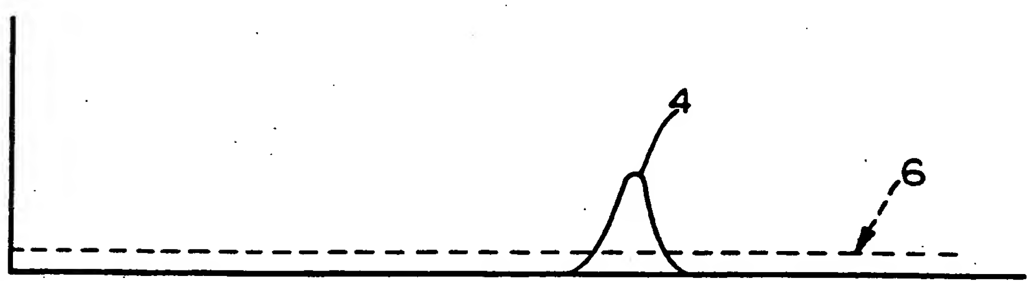

FIG 3

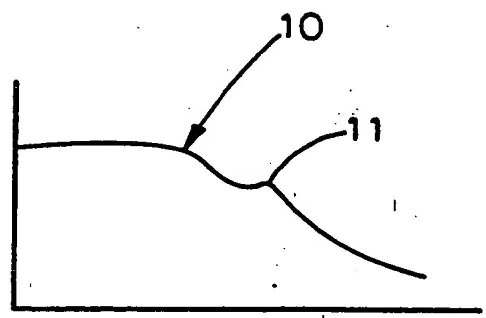

FIG 4

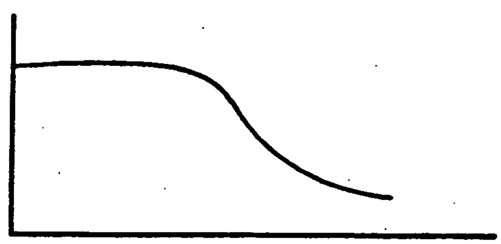

FIG 5

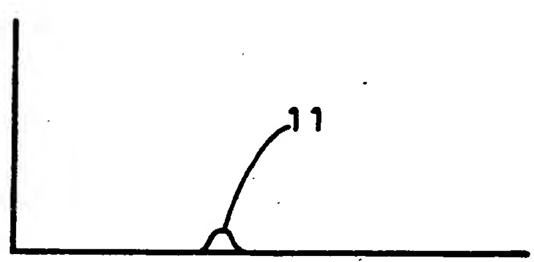

FIG 6

ACOUSTIC RANGE FINDING

The present invention relates to an acoustic range finding system, for example for monitoring the level of particulate solids or liquids, and to a method of acoustic range finding.

Acoustic range finding systems are known, for example from US-A-4 596 144 and EP-A-0 262 990, and are widely used for monitoring levels of material in tanks, silos and bins and for measuring the flow rates of liquids in channels or of particulate solids on conveyor belts by monitoring the level of material in the channel or on the conveyor belt. In these systems the level of material is monitored by transmitting a pulse or "shot" of high frequency or ultrasonic sound from a transducer towards the surface of the material and by determining the time lapse to reception of a return echo signal from the surface. The level of the material can then be calculated from the time lapse.

In practice, problems arise in isolating the return echo signal from acoustic noise in the form of spurious echoes, for example from the container, and electrical noise. Known acoustic range finding systems employ an analogue to digital converter to digitise the return echo signal and to store the digitised signal for later analysis. According

to US-A-4 596 144 the return echo signal is blanked during transmission of the shot and for a short time thereafter, because no wanted echo signal can be expected, and the wanted echo signal is isolated by looking for peaks in the digitised signal by repeatedly intersecting the echo profile with a straight line, possibly after first subtracting a curve from the digitised signal, the curve being calculated such that its amplitude approximates to the variation in gain of the system with time. The curve is recalculated for each processing operation. According to EP-A-0 262 990, the early part of the return echo signal is not blanked and can be tested for the presence of very short range signals by looking for any significant upturn in the echo profile which normally can only represent a true echo. In the event of spurious echoes occurring in the early part of the return echo signal, blanking is used to eliminate the unwanted echo. Alternatively, the echo search can simply begin at the point in the profile where the blanking would end, the echo profile itself remaining unblanked.

There is still a need to improve the detection of true echoes and to eliminate spurious echoes in order to improve the performance and reliability of acoustic range finding systems, particularly where very short range signals are concerned or where there are very strong spurious echoes.

It is an object of the present invention to provide an acoustic range finding system which is better able to detect very short range signals and to eliminate very strong spurious echoes.

According to one aspect of the present invention there is provided an acoustic range finding system including:

means for transmitting a first pulse of high frequency sound;

means for receiving a first echo in response to the first pulse from an environment in which the system is to be used;

means for storing a mask, the profile of which represents the variation of the first echo with time;

means for transmitting a second pulse of high frequency sound subsequent to the first pulse;

means for receiving a second echo reflected from the surface of material, within the environment, whose level it is desired to detect, and for converting the second echo into a return echo profile which represents the variation of the second echo with time;

means for subtracting the mask profile from the return echo profile so as to isolate substantially a true echo profile representative of the surface of material; and

means for examining the true echo profile in order to detect the true echo.

According to another aspect of the present invention there is provided a method of acoustic range finding, which method comprises the steps of:

transmitting a first pulse of high frequency sound;

receiving a first echo, in response to the first pulse, from an environment in which the method is to be used;

storing a mask, the profile of which represents the variation of the first echo with time;

transmitting a second pulse of high frequency sound subsequent to the first pulse;

receiving a second echo reflected from the surface of material, within the environment, whose level it is desired to detect, and converting the second echo into a return echo profile which represents the variation of the second

echo with time;

subtracting the mask profile from the return echo profile so as to isolate substantially a true echo profile representative of the surface of material; and

examining the true echo profile in order to detect the true echo.

The return echo profile may be stored.

The mask profile may be averaged over a plurality of first pulses and corresponding first echoes.

The length of the mask profile preferably corresponds to the extent of the environment within which a true echo can be expected.

A threshold may be superimposed onto the true echo profile.

The mask profile may be recalculated to allow for changes in the environment.

The mask profile may be extended on the basis of information taken from the return echo profile.

The mask profile may be modified on the basis of the return echo profile.

For a better understanding of the present invention and to show more clearly how it may be carried into effect reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a graphical representation of a return echo signal obtained by an acoustic range finding system according to the present invention;

Figure 2 is a graphical representation of a mask the profile of which is representative of the echoes generated within a vessel in which the range finding system is operative;

Figure 3 is a graphical representation of an echo signal following subtraction of the mask;

Figure 4 is a graphical representation of a return echo signal where the true echo is at very short range;

Figure 5 is a graphical representation of a mask corresponding to the return echo signal of Figure 4; and

Figure 6 is a graphical representation of the echo signal following subtraction of the mask.

Figure 1 shows a graphical representation of a return echo signal resulting from the transmission of a pulse of high frequency sound, receiving an echo reflected from the surface of a material the level of which it is desired to detect and storing the return echo profile. The echo profile represents the variation of the echo with time and comprises a first portion 1 in which the signal received saturates the receiver due to the transmission of the pulse or shot. In a second portion 2 of the profile the amplitude of the received signal is falling rapidly but is still sufficiently high to make it difficult to detect any true echo. In a third portion 3 of the profile the amplitude of the received signal has fallen substantially but it is still necessary to be able to distinguish between a true echo 4 from the surface of the material being measured and a spurious echo 5 due, for example, to multiple path reflections of walls, or reflections from obstructions or other structures in the environment defined within an enclosure.

Figure 2 shows a graphical representation of a mask profile which is formed by transmitting a pulse of high frequency sound before any level measurements have been attempted,

receiving an echo, for example from the walls of a vessel in which the system is to be used, from obstructions or other structures within the vessel, and storing the mask. The mask profile is determined by sampling the return echo signal for a period equivalent to the empty vessel distance. The return echo signal also includes any electrical noise arising within the system. If the mask shot is taken when the material level is very low, the resulting trace will include all spurious echoes 5 that could exist for any subsequent shot. By averaging the mask profile over a number of shots, we have found that a large proportion of the noise can be incorporated into the profile.

Using a predetermined mask profile, the mask profile can be subtracted from the return echo profile so as to isolate substantially a true echo profile 4 as can be seen from Figure 3. The true echo profile is representative of the surface of the material and can be examined in order to detect the position of the true echo and thus the level of material. The subtraction of the mask profile from the return echo profile makes the identification of a true echo 4, as distinct from a spurious echo 5, a relatively simple task and is adaptable to substantially any form of ultrasonic level measurement because the mask profile is built up from actual echoes and other noise from the

environment in which the measurement is to take place rather than being based on any profile that may be predetermined by the ideal performance of the system.

It is, however, not possible to employ a constant mask profile even though the mask is built up from actual spurious echoes. This is because the mask profile changes depending on, for example, the ambient temperature and the frequency and power of the shot. If such changes are small, a threshold (6 in Figure 3) can be superimposed on the true echo profile and the true echo profile will still have spurious echoes and noise eliminated therefrom. For larger changes, a new mask can be produced in a number of ways. For example, a new mask can be recalculated on the basis of the previous mask to allow for changes in temperature. Alternatively, for changing material levels, the mask can be extended from time to time to allow for falling material levels by extending the mask with information taken from the return echo profile. A further alternative is to modify the mask continuously on the basis of the return echo profile when there is a high degree of confidence that the true echo has been detected.

We have found that an acoustic range finding system according to the present invention which incorporates a mask profile that is adaptable to whatever environment

in which measurement is to take place allows accurate and reliable detection of true echoes and rejection of spurious echoes and noise. Moreover, if there is any change in the environment, the system is able to adapt to the change without giving erroneous measurements.

The use of an adaptable mask also has the advantage of removing the part of the return echo profile corresponding to ringing of the receiving transducer. This can be seen from Figures 4, 5 and 6 where the return echo profile 10 is shown in Figure 4 and shows a part of the profile where the receiver is saturated and part where the ringing is decaying rapidly. A true echo 11 only projects a short distance above the ringing signal and is difficult or impossible to detect with conventional methods. Figure 5 shows the part of the mask profile which is largely determined by saturation of the receiver during the shot and by ringing of the receiving transducer, but which can also incorporate spurious echo signals. As with Figure 2, the mask of Figure 5 is determined by taking one or more mask shots within the actual use environment and this permits the establishment of a mask that is dependent upon the actual environment and on the state of the receiving transducer at the time the mask is determined. Subsequent reassessments of the mask can be made, for example to allow for ageing of the transducer. Figure 6 shows the true echo

once the mask has been subtracted from the return echo profile.

We have found that the use of a mask that is adaptable to the actual environment enables the determination of a more accurate mask and enables us reliably to locate true echoes at very short range where ringing of the receiving transducer is significant and conceals a large part of the echo signal.

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CLAIMS

1. An acoustic range finding system including:

means for transmitting a first pulse of high frequency sound;

means for receiving a first echo in response to the first pulse from an environment in which the system is to be used;

means for storing a mask, the profile of which represents the variation of the first echo with time;

means for transmitting a second pulse of high frequency sound subsequent to the first pulse;

means for receiving a second echo reflected from the surface of material, within the environment, whose level it is desired to detect, and for converting the second echo into a return echo profile which represents the variation of the second echo with time;

means for subtracting the mask profile from the return echo profile so as to isolate substantially a true echo profile representative of the surface of material; and

means for examining the true echo profile in order to detect the true echo.

2. An acoustic range finding system as claimed in claim 1 and including means for storing the return echo profile.

3. An acoustic range finding system as claimed in claim 1 or 2, wherein the mask profile is averaged over a plurality of first pulses and corresponding first echoes.

4. An acoustic range finding system as claimed in claim 1, 2 or 3, wherein the length of the mask profile corresponds to the extent of the environment within which a true echo can be expected .

5. An acoustic range finding system as claimed in any preceding claim and including means for superimposing a threshold onto the true echo profile.

6. An acoustic range finding system as claimed in any preceding claim and including means for recalculating the mask profile to allow for changes in the environment.

7. An acoustic range finding system as claimed in any preceding claim and including means for extending the

mask profile on the basis of information taken from the return echo profile.

8. An acoustic range finding system as claimed in any preceding claim and including means for modifying the mask profile on the basis of the return echo profile.

9. An acoustic range finding system substantially as hereinbefore described with reference to the accompanying drawings.

10. A method of acoustic range finding comprising the steps of:

transmitting a first pulse of high frequency sound;

receiving a first echo, in response to the first pulse, from an environment in which the method is to be used;

storing a mask, the profile of which represents the variation of the first echo with time;

transmitting a second pulse of high frequency sound subsequent to the first pulse;

receiving a second echo reflected from the surface of

material, within the environment, whose level it is desired to detect, and converting the second echo into a return echo profile which represents the variation of the second echo with time;

subtracting the mask profile from the return echo profile so as to isolate substantially a true echo profile representative of the surface of material; and

examining the true echo profile in order to detect the true echo.

11. A method according to claim 10 and including the step of storing the return echo profile.

12. A method according to claim 10 or 11, wherein the mask profile is averaged over a plurality of first pulses and corresponding first echoes.

13. A method according to claim 10,11 or 12, wherein the length of the mask profile corresponds to the extent of the environment within which a true echo can be expected.

14. A method according to any one of claims 10 to 13 and including the step of superimposing a correction onto the mask profile.

15. A method according to any one of claims 10 to 14 and including the step of recalculating the mask profile to allow for changes in the environment.

16. A method according to any one of claims 10 to 15 and including the steps of extending the mask profile on the basis of information taken from the return echo profile.

17. A method according to any one of the claims 10 to 16 and including the step of modifying the mask profile on the basis of the return echo profile.

18. A method of acoustic range finding substantially as hereinbefore described with reference to the accompanying drawings.